by cropping without much effort to replace the phosphates by the use of fertilizers. The value of phosphorus in hastening maturity is well known.

CONCLUSIONS

Placed in the order of rank it is believed that the causes of the increase in frosted corn are about as follows: (1) Breeding for increased yield; (2) decrease in available phosphorus in the soil; (3) later planting due to later frost date and other unfavorable weather conditions. Slight but inappreciable tendencies that should have operated in the direction of improved maturity have been: (1) Later autumn frosts; (2) upward trend in seasonal temperature and also in the temperature of the month of May.

All weather tendencies will probably disappear when a sufficient length of record has accumulated.

SOME RESULTS OBTAINED BY TESTING SOLARIMETERS WITH PYRHELIOMETRIC TUBES

By LADISLAUS GORCZYŃSKI

INTRODUCTION

A large number of comparative readings of solarimeters and pyrheliometric tubes have been made, particularly from March to August, 1927, in Ariana, Tunis, and at Montpellier, in the south of France. It seems desirable to present a short discussion of results obtained at these places and also of the important series obtained at the solar observatory of the United States Weather Bureau through the cooperation of Dr. Herbert H. Kimball and Mr. Irving F. Hand. Furthermore, through the results obtained with pyrheliometric tubes with the receiving surface at normal incidence to the solar rays gave a constant reduction factor, the standardization of the solarimeter, employed for measurements of solar and sky radiation on a horizontal surface, has shown that cover glasses of sufficient diameter are necessary to obtain a reduction factor which will be independent of solar altitude. For the establishment of this important relation I am indebted to Dr. H. H. Kimball, who suggested that the use of larger cover glasses would be essential if caustic and other deflections of the solar rays were to be eliminated. This suggestion has been fully confirmed by the extensive series of measurements made at Montpellier.

In the following sections are presented the results obtained from comparative measurements of solarimeters and pyrheliometric tubes, and it is proven that by using cover glasses 50 millimeters in diameter and 1 millimeter thick the solarimeter coefficients are practically independent of the variable altitude of the sun. Results obtained with pyrheliometric tubes are also tabulated and indicate that the probable error of the reduction factor is small. Values of diffuse sky radiation are also tabulated.

THE TESTING OF PYRHELIOMETER TUBES IN CONNECTION WITH SOLARIMETER BOXES

The pyrheliometer tubes are tested in connection with solarimeter boxes, the construction of which was described in my paper published in the September, 1926, REVIEW, 54:381–384. It will be recalled that the solarimeter is a small portable instrument for measuring solar radiation not only as received upon a horizontal surface but also by the addition of a pyrheliometric tube, the intensity of direct solar radiation at normal incidence. (See fig. 1.)

Using an equatorial mounting and a registering millivoltmeter, a pyrheliograph for automatic recording is easily obtained (fig. 2). The old-style register with inked pen and paper for only 24 hours has been replaced with a new recording millivoltmeter using typewriter ribbons and a continuous roll of paper, which provides for several days of record without attention.

Referring to my paper in the REVIEW for June, 1924, 52:299–301, Figures 1 and 2, it will be recalled that the thermopiles are made of thin plates of manganan and constantan of low resistance (about 8 ohms), with the active junctions arranged on a straight line in the center. In the newer type the thermoelements are covered with a special lacquer and form a rectangular surface without intervening spaces. This is important for horizontal exposure, as it avoids the varying influence of oblique solar rays. The pile is hermetically sealed in dry air under a cover of special flint glass. Those used in the pyrheliometric tubes are of similar construction but differ in the mounting. A sphero-cylindrical lens is generally placed in the outer end of the tube, thus obtaining about a fourfold magnification of intensity. The use of this lens is not obligatory, but it is useful in measuring low intensities, particularly when light filters are employed. An ordinary plain protecting glass is sufficient to obtain good deflections, which can be increased by using a more sensitive galvanometer. For our tests made in the south of France, mostly by my assistant, Mr. L. Lemanski, we have used a pyrheliometric tube with a plain glass. For the comparisons, simultaneous measurements were made with an Ångström electrical compensation pyrheliometer recently received and calibrated. The coefficient value (k) as determined by Doctor Bäcklin at the physical institute of the University of Upsala, Sweden, during the summer and autumn of 1926 was 14.9. The agreement is very good between this value, obtained by comparisons with Ångström's Standard No. 78, and the value

$$K = 60/4.19 \; . \; r/b. \; a. = 14.93$$

where "r," the resistance = 0.2101, Ohm/cm, "b," the width of the strips = 0.2057 cm., and "a," the absorption coefficient = 0.98. For final computations, we have adopted, however, a coefficient value

$$k' = k \times 1.034 = 1.54$$

by adding the well-known correction for the border effect.

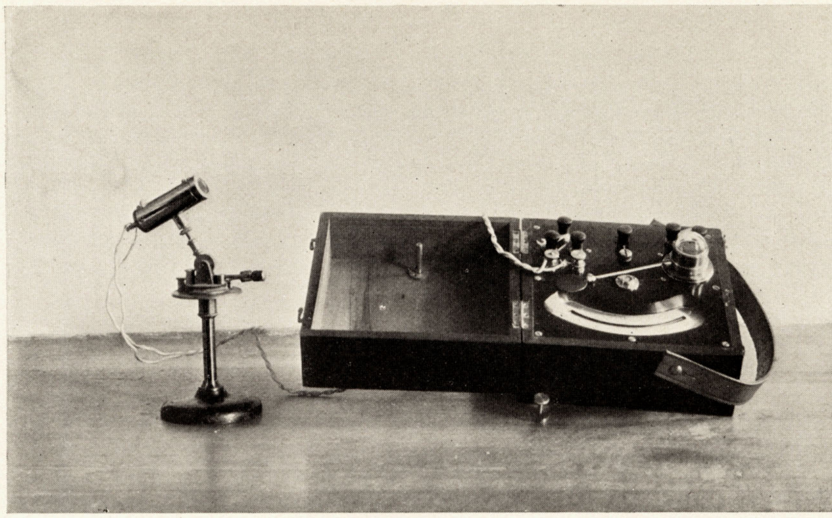

FIG. 1.—Pyrheliometric tube and solarimeter box

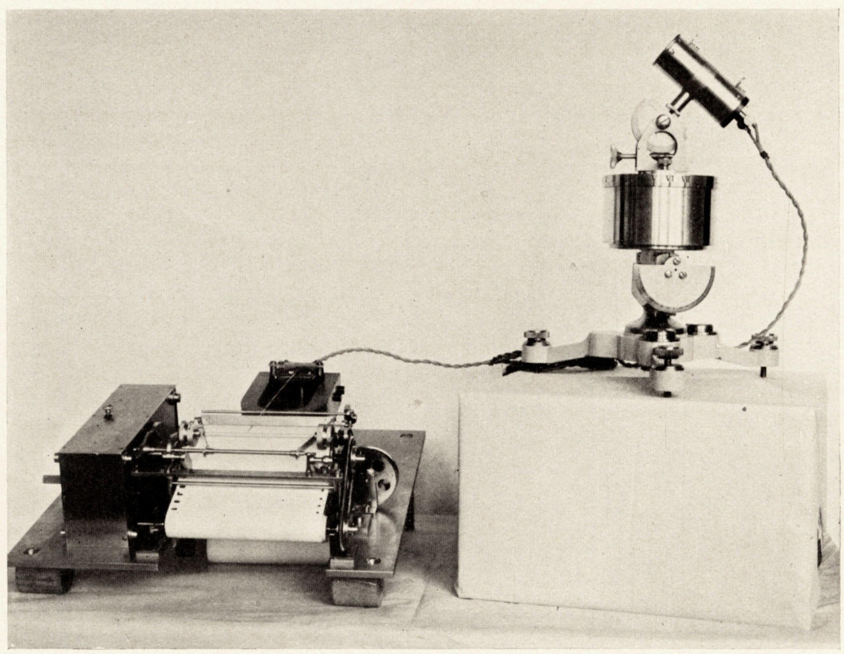

FIG. 2.—Pyrheliometric tube with equatorial mounting connected to a recording voltmeter

FIG. 3.—Solarimeter box with attached solar screen

Reduction factor for a Gorczyński pyrheliometric tube normally exposed to sun's rays

[Value of 1 scale division of millivoltmeter No. 4957 (gr. cal. cm.$^{-2}$ min.$^{-1}$)]

1927	Coefficient	1927	Coefficient
June 21	0.01567	Aug. 3	0.01553
June 22	579	Aug. 10	560
June 24	571	Aug. 12	568
June 28	.01559	Aug. 13	555
July 1	.01560	Aug. 16	563
July 5	575	Aug. 17	563
July 11	568	Aug. 19	560
July 12	557	Aug. 20	562
July 13	550	Aug. 26	556
July 14	553	Aug. 27	563
July 15	563	Aug. 28	552
July 17	561	Aug. 31	.01563
July 18	546		
July 19	569		
July 20	546		
July 21	557		
July 30	.01554		
Mean value	.01561	Mean value	.01560

Table 1 shows the results of the comparisons between Ångström pyrheliometer No. 178 and our pyrheliometer tube mounted on a special holder and connected with a galvanometer (millivoltmeter No. 4957). We give the results of only 29 days during the period June–August, 1927, when these comparisons were particularly numerous and made during several hours every day. We add, however, that the mean coefficient value for our pyrheliometer tube obtained in 1926 and the first half of 1927 is in good accord with Table No. 1, showing a satisfactory constancy of the reduction factor, 0.0156, for different days and different altitudes of the sun.

The individual daily values are calculated as means of several (about 10) comparisons between the Ångström compensation pyrheliometer and our pyrheliometric tube. The daily reduction factors do not vary if the sky conditions are good; but clouds and foggy weather give greater departures, but even these do not exceed ± 1 per cent. This is clearly shown by an example given in Table 2 on a day with very poor sky conditions.

TABLE 2.—*Example of variations in the coefficient value (reduction factor of the pyrheliometer tube connected with millivoltmeter No. 495F)*

[Montpellier, France, Aug. 26, 1927]

Time	Gram-calories (Ångström pyrheliometer)	Pyrheliometer tube: Scale reading	Pyrheliometer tube: Coefficient (F)	Sky condition (nebulosity)
h. m.				
6 42	0.66	42.6	0.0154	Foggy (mist) and windy.
7 04	.84	54.0	156	Do.
7 31	.94	60.3	156	Neb. 3 veils.
7 52	1.00	63.0	157	Do.
8 19	1.04	66.5	157	Do.
9 16	1.11	70.6	157	Neb. 6 } Frequent passages of clouds before the sun.
10 10	1.17	75.1	155	Neb. 7
10 39	1.19	76.9	155	Neb. 8
11 09	1.18	76.2	155	Neb. 9

N. B.—Very bad sky conditions in the morning hours. Frequent passages of clouds before noon. Sky covered (nebulosity 10) after 11 a. m.

To standardize a thermopile with its receiving surface exposed horizontally under a glass cover, as in the case of the solarimeter, it must be remembered that the pile receives scattered radiation from the sky as well as direct radiation from the sun, and that the effect of the glass cover must not be overlooked. In the REVIEW for *August, 1914, 42 : 477, Figure 5, and for May, 1923,* **51** : 241, Figure 4, Kimball has shown that by the use of a screen the radiation (S) received from the sky may be separated from the record of the total radiation (T). Then, to obtain the factor *F*, by which to reduce the solarimeter scale readings to heat units we have the equation

$$F=\frac{\mathrm{Q}\sin \mathrm{h}}{\mathrm{T-S}}$$

where Q is the intensity of the solar radiation at normal incidence measured by a standard pyrheliometer, and h is the altitude of the sun at the time of the measurement. Example:

Scale reading of solarimeter before exposure to sun and sky	0.3
Scale reading of solarimeter when exposed to sun	46.5
Scale reading of solarimeter with direct sunlight cut off by screen	4.5
Scale reading of solarimeter after exposure to sun and sky	0.1
Scale reading corresponding to radiation from sun and sky	46.3
Scale reading corresponding to radiation from sky	4.3
Scale reading corresponding to vertical component of radiation from the sun alone	42.0

Solar radiation intensity at normal incidence 1.38 gr. cal. per min. per cm.^{2}, solar altitude 67.2°, sine 67.2° = 0.922

$$F=\frac{1.38\times 0.922}{42.0}=0.0303$$

Figure 3 shows a solarimeter with a solar screen so attached that it can always be made to shield the receiving surface of the thermopile from the direct rays of the sun.

Comparisons like the above made by Kimball and Hand at the American University, District of Columbia, showed that with glass covers of small diameters the value of *F* varied with the altitude of the sun. The numerous comparisons made under the direction of the writer in Tunis and France confirmed their results, and showed, further, that the thickness of the glass as well as the diameter of the cover is a contributing factor to the variations.

In Table 3 are given the results of tests made with cover glasses of different diameters and thicknesses. The results are given for only a single day with each cover glass. They indicate that with cover glasses 50 millimeters in diameter or over and 1 millimeter thick there is no appreciable variation in the value of *F* with variation in the solar altitude.

Table 4 includes all the tests made with cover glasses 50 millimeters in diameter and 1 millimeter thick; Table 5 the tests with cover glasses 40 millimeters in diameter and 1 millimeter and 2 millimeters thick; and Table 6 the tests with cover glasses 30 millimeters in diameter and 1 millimeter and 2 millimeters thick. These tests confirm what was shown in Table 3.

TABLE 3.—*Changes of solarimetric coefficients (reduction factors) for different sizes of glass-cover (in per cent of the value obtained at or near noon)*

Diameters in centimeters (thickness in millimeters)	Date	Sun's altitude 70°	60°	50°	40°	30°	20°	10°
Cm. Mm.	1927	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
106 (1)	July 5, p. m.	0	0	0	0	0	+1	------
80 (1)	Aug. 1, p. m.	------	0	0	0	0	0	------
50 (1)	Aug. 28, p. m.	------	------	0	0	+2	0	−2
40 (1)	July 25, p. m.	------	0	0	0	0	+1	+4
40 (2)	do	------	0	------	+3	------	+10	+18
38 (2)	June 20, a. m.	------	0	+1	+3	+4	+8	------
30 (1)	do	------	0	+2	+4	+6	+9	------
30 (2)	June 21, a. m.	0	0	+1	+3	+6	+19	+24

TABLE 4.—*Changes of solarimetric coefficients (reduction factors) for a glass cover of 50 millimeters in diameter and 1 millimeter in thickness (in per cent of the value obtained at or near noon)*

1927	Sun's altitude						
	70°	60°	50°	40°	30°	20°	10°
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
June 24, a. m.	0	+2	+1	−1	−1	....	....
June 24, p. m.	....	0	−2	−1	+1	....	....
July 26, a. m.	0	+1	+2	+1	−5	−6	....
July 30, a. m.	....	0	−2	−5	−7	....	....
July 30, p. m.	....	0	....	....	−3	−6	....
Aug. 1, a. m.	....	0	....	....	−4	....	....
Aug. 1, p. m.	....	....	0	−1	....	+6	....
Aug. 3, a. m.	....	0	0	+1	0	....	....
Aug. 3, p. m.	....	....	0	−2	+1	....	....
Aug. 10, p. m.	....	....	0	0	+2	+3	+5
Aug. 28, p. m.	....	....	0	0	+2	0	−2
Aug. 30, a. m.	....	0	0	−1	−5	....	....
Aug. 30, p. m.	....	0	0	+2	....	+4	....
Mean	....	....	....	−0.6	−1.7	+0.2	(+1.5)

TABLE 5.—*Changes of solarimetric coefficients (reduction factors) for a glass cover of 40 centimeters in diameter (in per cent of the value obtained at or near noon)*

A. DIAMETER, 40 CENTIMETERS; THICKNESS, 1 MILLIMETER

1927	Sun's altitude							
	60°	50°	40°	35°	30°	25°	20°	15°
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
July 24, p. m.	....	0	+1	+3	+5	+8	+11	+14
July 25, p. m.	....	0	0	0	0	+1	+2	....
Aug. 10, p. m.	....	....	0	−3	−5	−3	−2	−3
Aug. 27, p. m.	....	0	0	0	−1	−3	−5	....
Aug. 28, p. m.	....	0	0	0	0	−3	−6	....

B. THE SAME DIAMETER; THICKNESS, 2 MILLIMETERS

July 24, p. m.	....	0	0	+1	+3	+5	+8	+11
July 25, p. m.	0	0	+2	....	+5	....	+10	....

TABLE 6.—*Increase of solarimetric coefficients (reduction factors) in function of sun's altitude for a glass cover of 30 centimeters in diameter (in per cent of the value obtained at or near noon)*

A. DIAMETER, 30 CENTIMETERS; THICKNESS, 2 MILLIMETERS

1927	Sun's altitude							
	60°	50°	40°	35°	30°	25°	20°	15°
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Apr. 11	....	....	0	5	....	....	....	12
Apr. 13	....	....	0	3	6	9	....	....
Apr. 14	....	0	6	12	15	21	24	47
Apr. 16	....	....	0	3	6	9	12	18
Apr. 19	....	0	3	6	10	....	....	....
Apr. 21	....	0	3	9	12	18	24	29
Apr. 22	....	0	2	5	10	....	....	....
June 6	0	4	8	10	12	15	21	35
June 9	0	0	3	6	12	....	....	....
June 21	0	0	3	6	9	12	18	25
June 22	0	0	5	12	18	....	....	....
June 24	0	0	8	14	18	25	....	....
June 28	0	0	6	12	16	21	25	....
Mean	....	....	4	8	12	16	21	28

B. DIAMETER, 30 CENTIMETERS; THICKNESS, 1 MILLIMETER

Apr. 18, a. m.	0	0	0	0	3	6	9	....
Apr. 18, p. m.	0	1	3	6	9	12	....	....
Apr. 20, a. m.	0	3	6	9	10	12	15	18
Apr. 20, p. m.	0	3	6	9	12	18	21	....
Apr. 21, a. m.	0	0	0	0	0	0	....	....
Apr. 21, p. m.	0	0	3	4	5	6	9	18
Apr. 12, p. m.	0	3	10	12	14	16	18	....
Mean	....	....	4	6	8	10	14	18

In connection with these comparisons many measurements of sky radiation have been obtained. Expressed as a percentage of the total radiation (sun and sky) they show, in Table 7, a marked diurnal variation, with the maximum near noon. Table 8, which includes only midday measurements, gives a mean value for the period March 5 to August 30 of 10 per cent, with considerable variations in the values from day to day.

TABLE 7.—*Diurnal variation in the ratio* $\frac{\textit{sky radiation}}{\textit{solar radiation}}$, *expressed as a percentage*

Hours	Per cent	Hours	Per cent
11–13	12	6–7	24
13–16	12	7–8	17
16–17	20	8–9	13.5
17–18	28	9–11	12
18–18.30	39		

TABLE 8.—*Minimum diurnal values of the diffuse sky radiation (generally observed between 11 and 13 hours)*

[After solarimetric measurements made at Montpellier, France (Mar. 28–Aug. 30) and Ariana, Tunis (Mar. 5 and 7)]

1927	Per cent	1927	Per cent
Mar. 5	9	June 16	19
Mar. 7	13	June 17	11
Mar. 28	8	June 18	12
Mar. 30	9	June 20	6
Apr. 14	7	June 21	6
Apr. 19	10	July 2	12
Apr. 20	10	July 5	8
Apr. 21	10	July 11	10
Apr. 22	11	July 12	10
Apr. 26	8	July 13	9
May 1	9	July 14	11
May 11	13	July 15	10
May 12	13	July 17	11
May 13	12	July 18	11
May 14	9	July 19	10
May 23	13	July 20	13
May 24	9	July 21	8
May 25	9	July 22	12
May 28	11	Aug. 27	14
June 6	9	Aug. 30	18
June 7	8		
June 9	12	Mean (March–August)	10

SUMMARY

In continuation of my paper on "Solarimeters and Solarigraphs" (MONTHLY WEATHER REVIEW, September, 1926, **54**:381–384), it is here shown that, (1) a constant reduction factor is obtained from pyrheliometric tubes for extensive series of comparisons made at Ariana, Tunis, and Montpellier, France; (2) from solarimeter tests it is shown that, following a suggestion of Dr. H. H. Kimball, the coefficient values are independent of the solar altitude only when the cover glasses are of sufficient diameter; (3) that a cover glass 50 millimeters in diameter and 1 millimeter thick gives satisfactory results. Cover glasses 30 millimeters in diameter and 2 millimeters thick show an increase of 20 to 30 per cent (average values with clear sky) in the reduction factor with the sun near the horizon, as compared with the factor obtained with the sun near the zenith.

Some data for diffuse-sky radiation are given at the end of the paper.